Geophysics and QA/QC for UXO Detection

Munitions Response Workgroup

NSWC Indian Head, MD

June 26, 2003

Geosoft Inc.

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Overview

- Introduction to Geosoft Inc.
- The UXO Problem
- How Geophysics Helps
- QA/QC Software Tools
- Training Sessions
- Questions

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What is Geosoft?

- Team of 60+ professionals in 5 countries
- Established in 1982
- Software and services company
- Began with geophysical data processing, interpretation and presentation
- Now: mining, petroleum, marine, environmental, government and UXO
- Offer Oasis montaj and partner software, customized services, and business solutions

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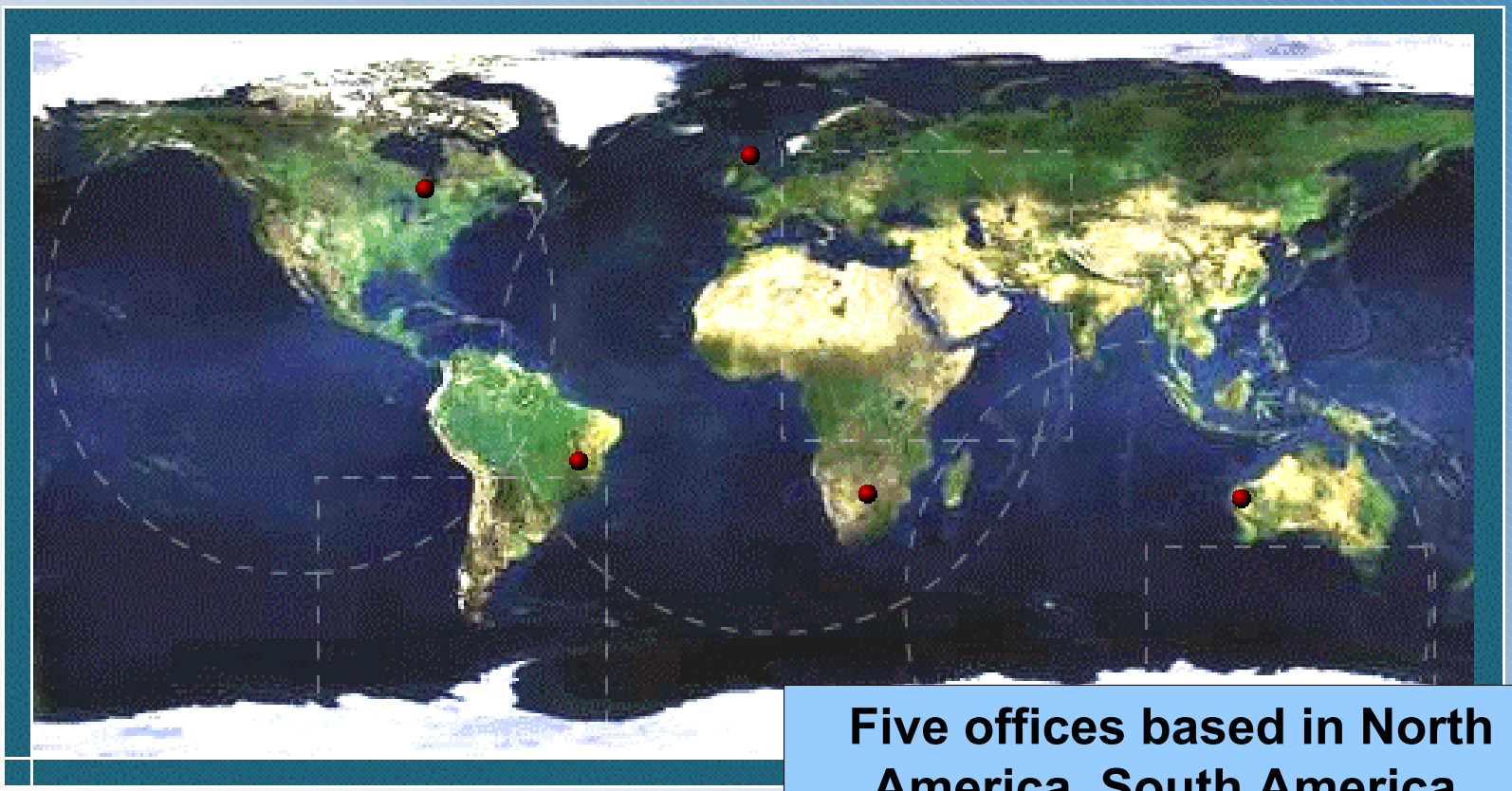
Geosoft Offices



Five offices based in North America, South America, Europe, Africa and Australia

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The UXO Problem

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Detecting UXO

Many sources of UXO uncertainty:

- Huge areas of land to be covered
- Complex processing and interpretation
- Geology (clays, massive volcanics, etc.)
- Instrument noise
- Targets – need to know location, type & depth

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The Solution: Geophysics

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Welcome to Geophysics 101

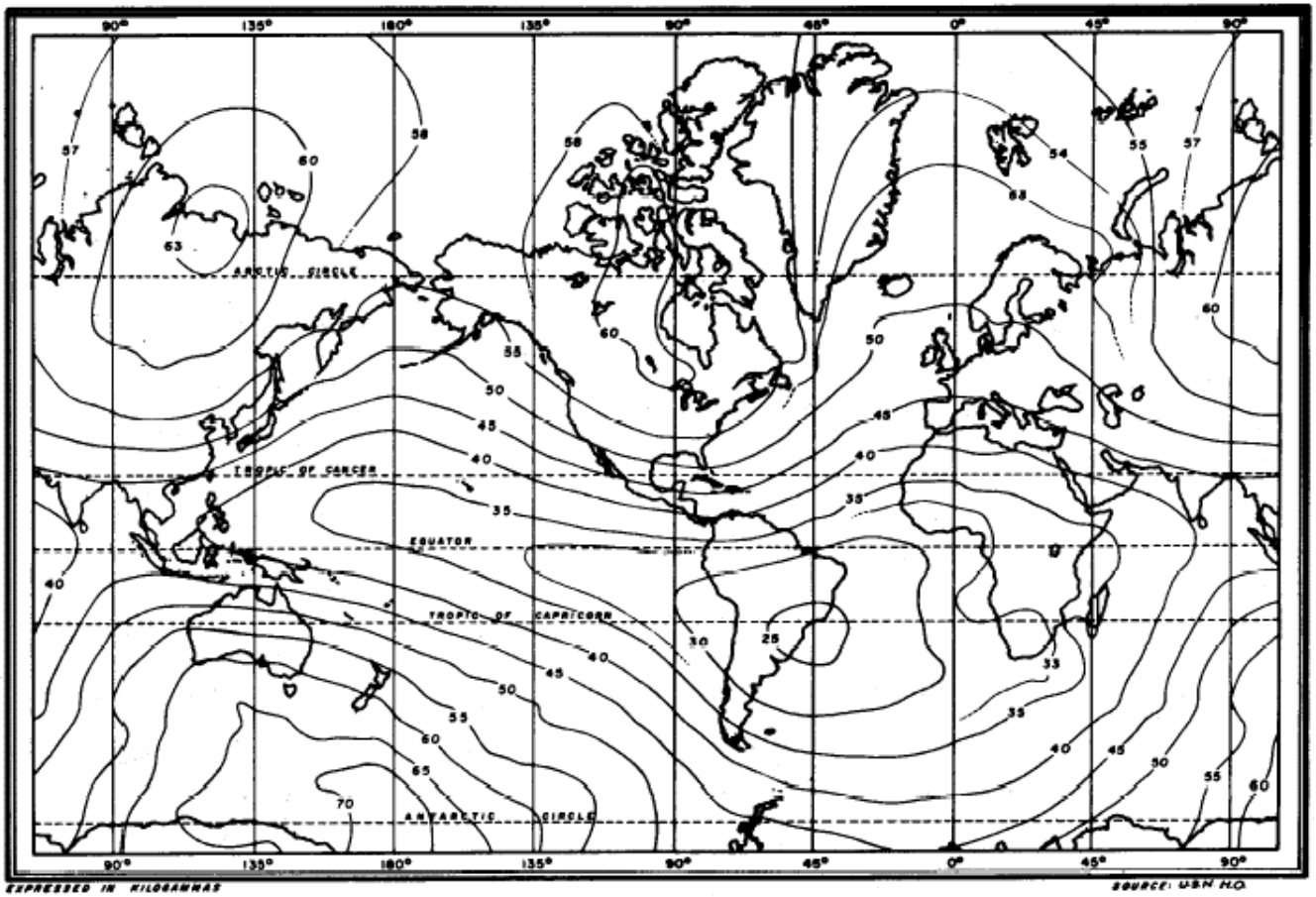

Figure 4. The Total Intensity of the Earth's Magnetic Field

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Initial Method: “Mag & Flag”

- Hand-held metal detector (magnetometer)
- Instrument detects an anomaly (beeps)
- Small flag is placed in ground
- Benefits: covers areas which are difficult to traverse; good for small areas
- Disadvantages: all shallow targets are marked; misses deeper targets

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Disadvantages of Mag & Flag

Photo courtesy of Bob Selfridge, US Army Corps of Engineers – Huntsville Center

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Traditional Method: Geophysical Surveys

- Use of geophysics for UXO detection has evolved over past 5-10 years
- Surveys are typically: mag, EM-61 and GPR
- Coupled to a navigation system such as Global Positioning System (GPS)
- Detects the ferrous content or electrical conductivity properties of buried materials

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Benefits of Geophysical Mapping

- Studies show: more effective than “mag & flag”
- Improved detection and reduction of false positives
- Provides archival records
- Builds a digital map of the anomalies in the area being surveyed
- Significant advantages when surveying large areas, searching for pits and trenches, and areas where items may be buried deeper than a hand-held instrument can detect

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Designing Geophysical Surveys

- Understand what you are trying to find (2000 lb bombs vs. 20 mm shells)
- High sampling density needed to improve understanding of source:
  - typical sampling interval = 5 - 25 cm
  - typical line spacing = 0.5 - 1.0 m
- Choose instruments: mag vs. EM vs. GPR or combinations
- Configuration - sensor height, coil separation and size, etc.

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Magnetometers

Land:

- Scintrex ENVI Mag and SMARTMAG
- Geometrics G-858 Cesium, G-856 Proton
- GEM GSM-19, GSM-19T, GSM-8, GSM-9

Marine:

- Geometrics G-880, G-881 and G-877
- GEM GSM-19M

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Magnetics at Work

- Object with ferrous content acts as a magnet
- Magnetometer induces a current in the buried item which in turn produces it's own magnetic field which is detected by the instrument

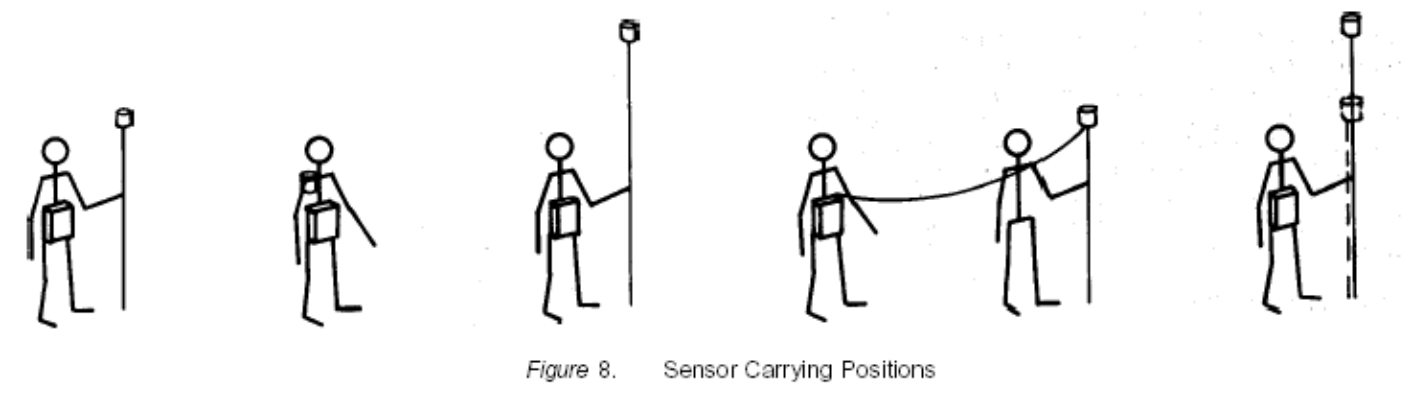

Figure 8. Sensor Carrying Positions

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Benefits of Magnetometers

- sensitivities of <1 nT
- many UXO contain a considerable amount of ferrous material
- can be used to determine the approximate location of a ferrous anomaly by the field of its dipole moment
- size of an object can also be determined from the size and orientation of the induced moment

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Electromagnetic Induction

- Traditionally, only Geonics EM-61 used
- Various coil configurations (1x1m, 1x0.5m, 0.5x0.5m, EM-61 HH)
- EM-61 Mark II (4 time gates) and EM-63 now being used, as well as Zonge NanoTEM instrument
- EM-31 is sometimes used

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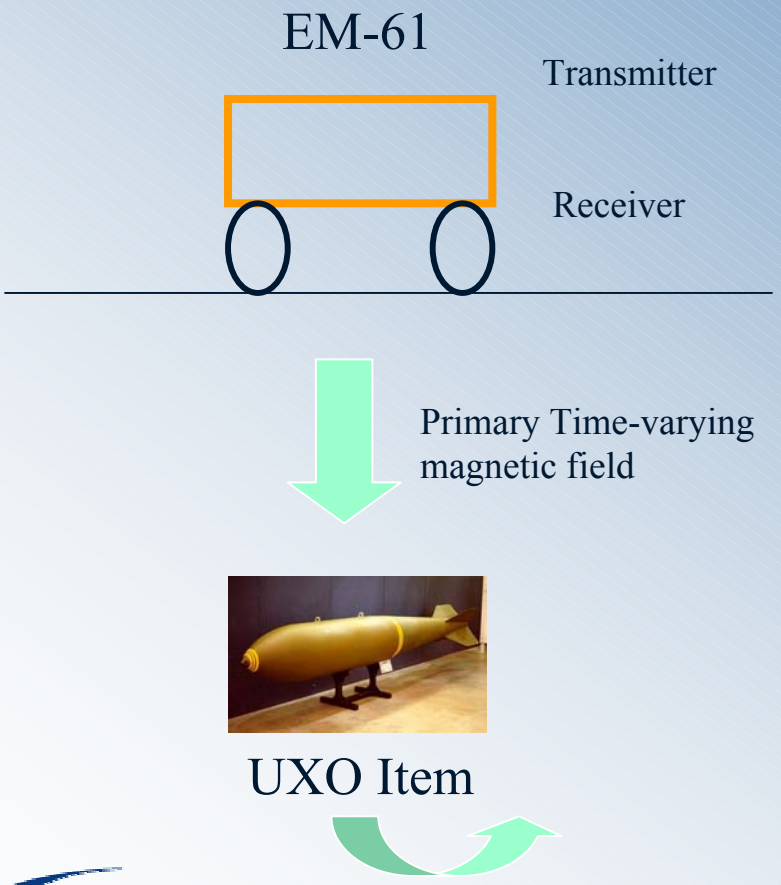
EM at Work



- Transmitter generates a pulsed primary magnetic field in the earth (a time-varying magnetic field)
- Detects the secondary magnetic field produced by the eddy currents induced in the object
- Induces eddy currents in buried metallic objects
- Eddy current decay produces a secondary magnetic field measured by the receiver coil
- By taking the measurement at a relatively long time after the start of the decay, the current induced in the ground has fully dissipated and only the current in the metal is still producing a secondary field
- Responses are recorded and displayed by an integrated data logger

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Benefits of EM-61

- Time-domain metal detector
- Detects both ferrous and non-ferrous metals
- Relatively insensitive to interference from nearby surface metal such as fences, buildings, cars, etc
- Response is a single, sharply defined peak
- Depth of the target can usually be estimated from the width of the response

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QA/QC Software

- Funded by Environmental Security Technology Certification Program (ESTCP)
- Earlier efforts as a geophysical analysis tool set (UHUNTER)
- Directed by CEHNC to coincide with their efforts on documenting and standardizing QA/QC field procedures

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ESTCP

Purpose

- Need → poor results based on poor data
- Standardize QA/QC processes within the UXO community to:
  - Improve data quality
  - Improve detection methods
- Provide a software platform for algorithm-sharing (focused to SERDP/ESTCP efforts)

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Benefits

- Runs under Geosoft's free version of Oasis montaj
- Helps identify and correct instrument/acquisition errors prior to demobilization
- Less reworking of areas = cost savings

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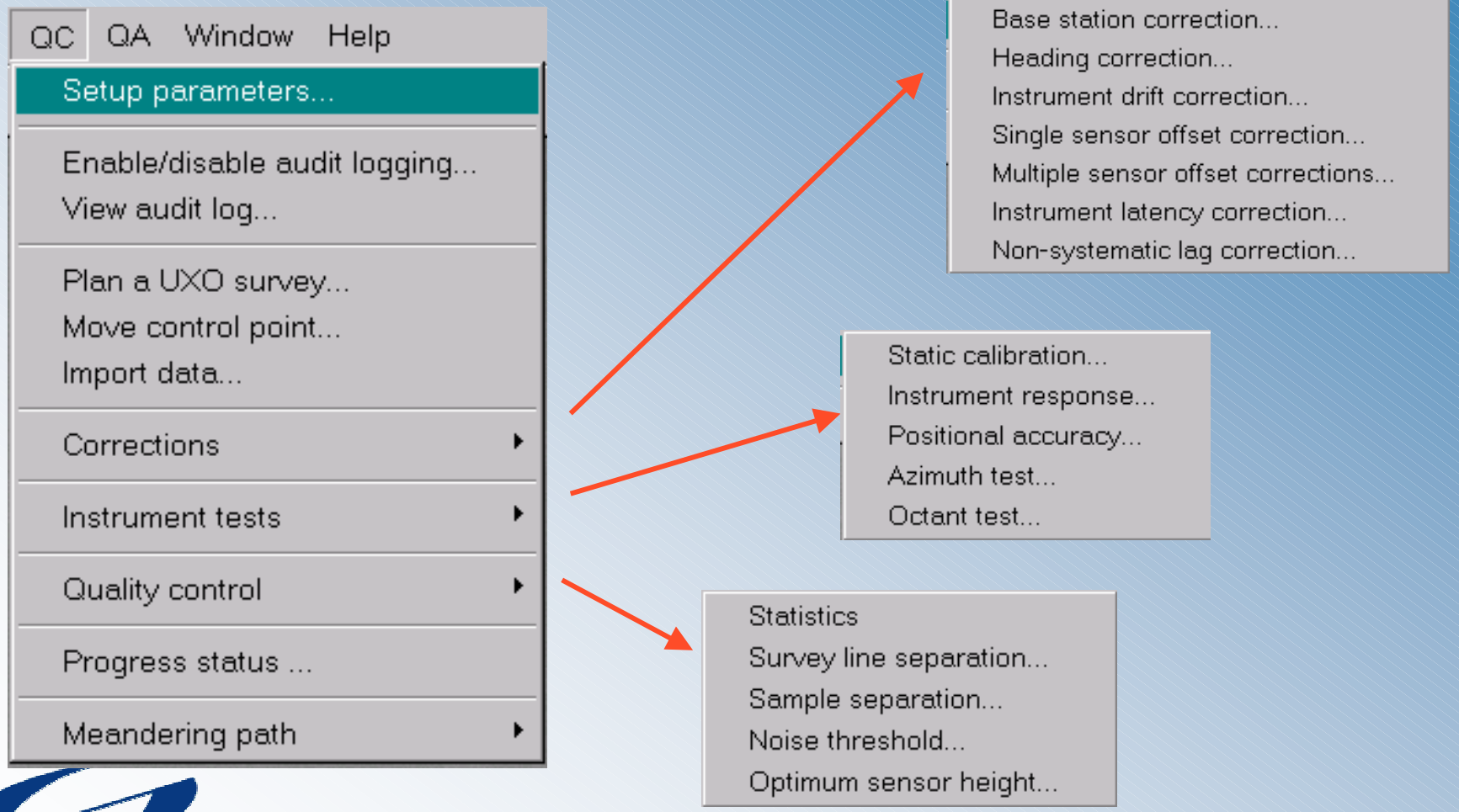
Quality Control (QC) Module



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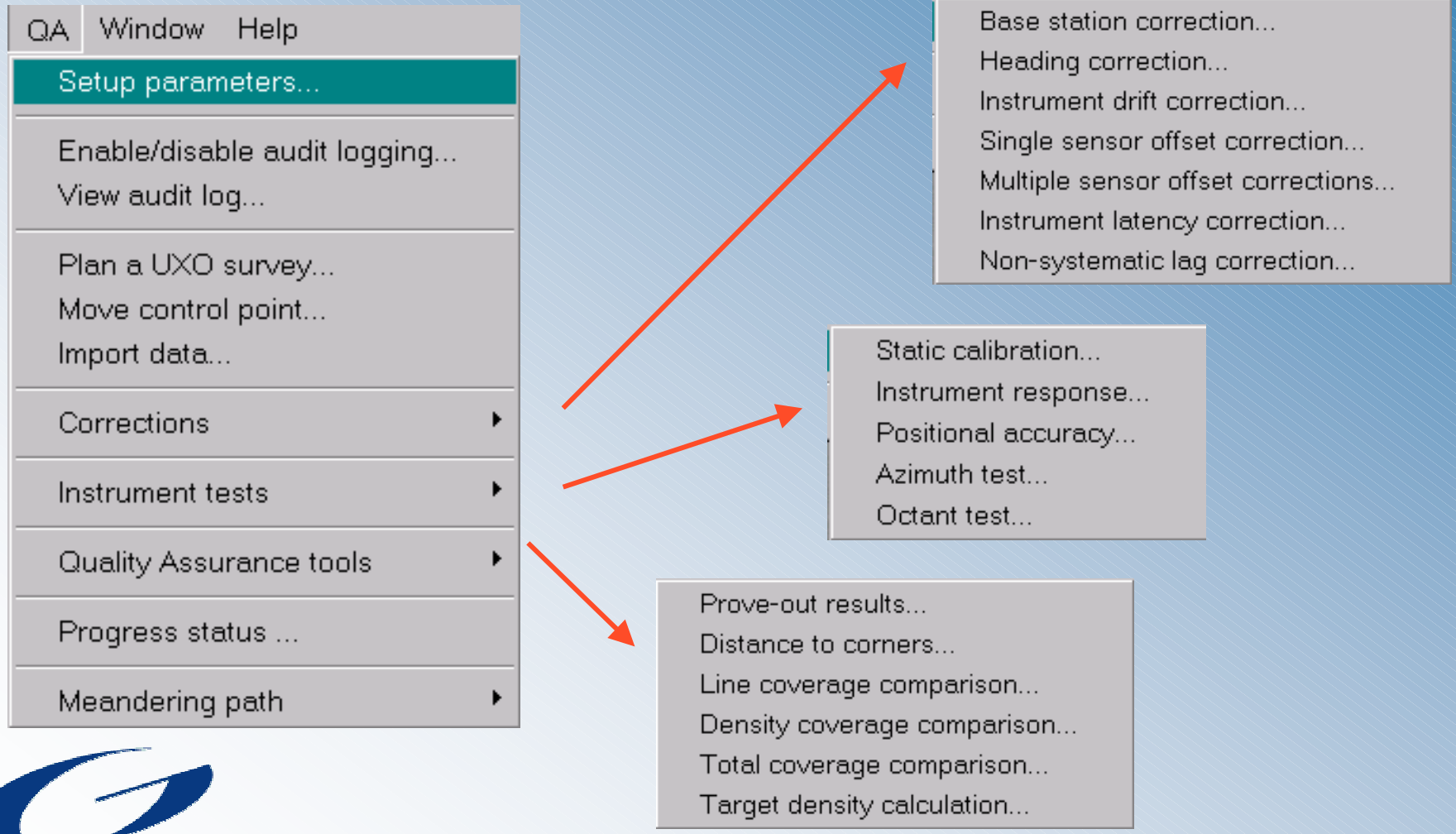
Quality Assurance (QA) Module



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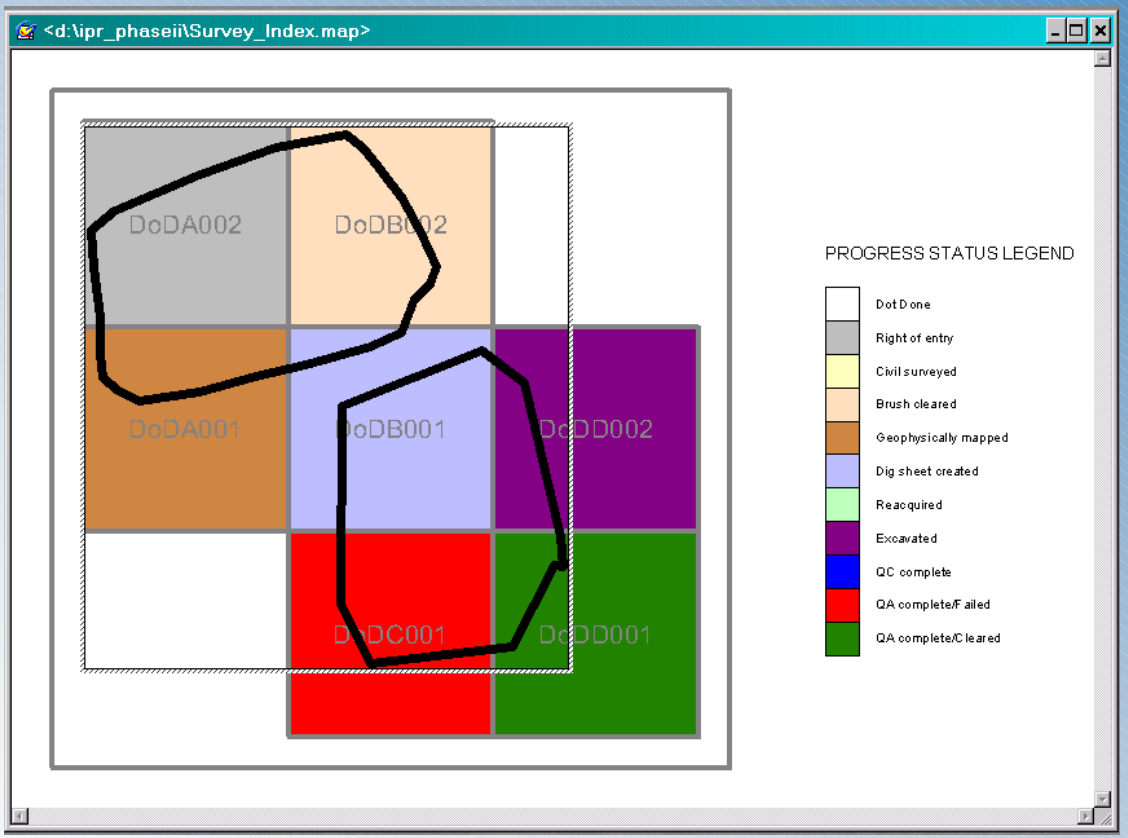
Completed Software



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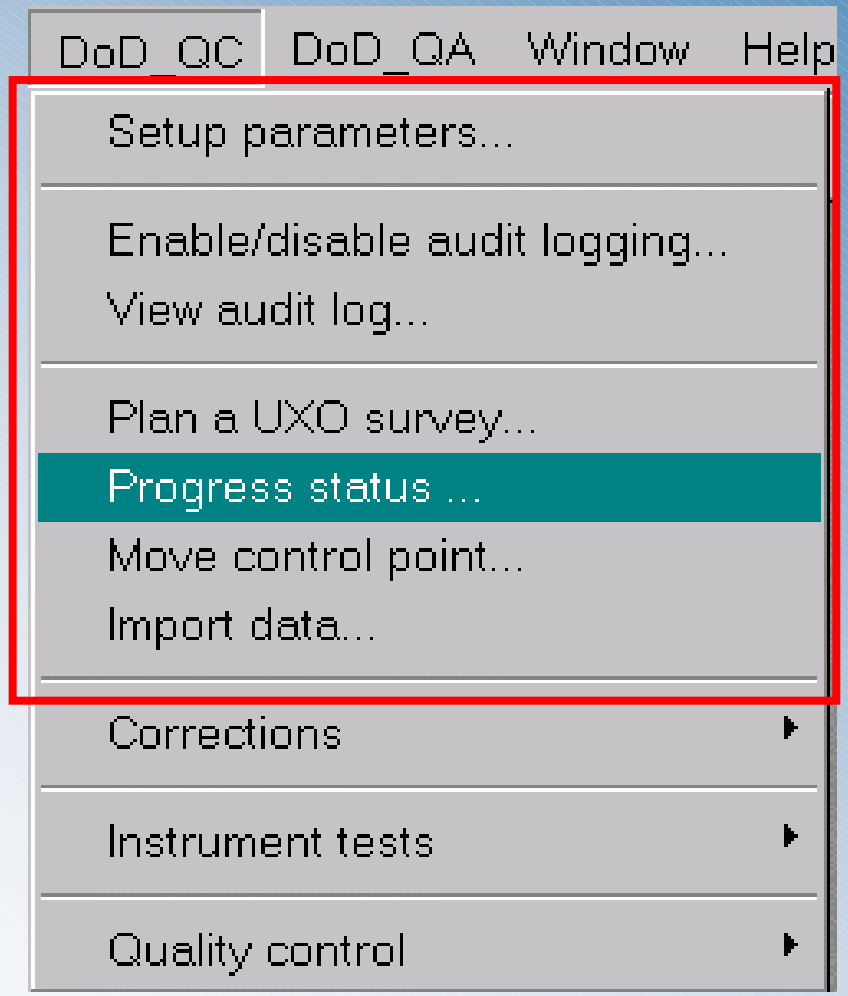
Survey Planning Tools



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Survey Planning Tools

- Setup Parameters → stores project info, including projection
- Audit log → tracks what has been done to data
- Plan a UXO Survey → pre-design a UXO survey
- Import → import data from a variety of instruments

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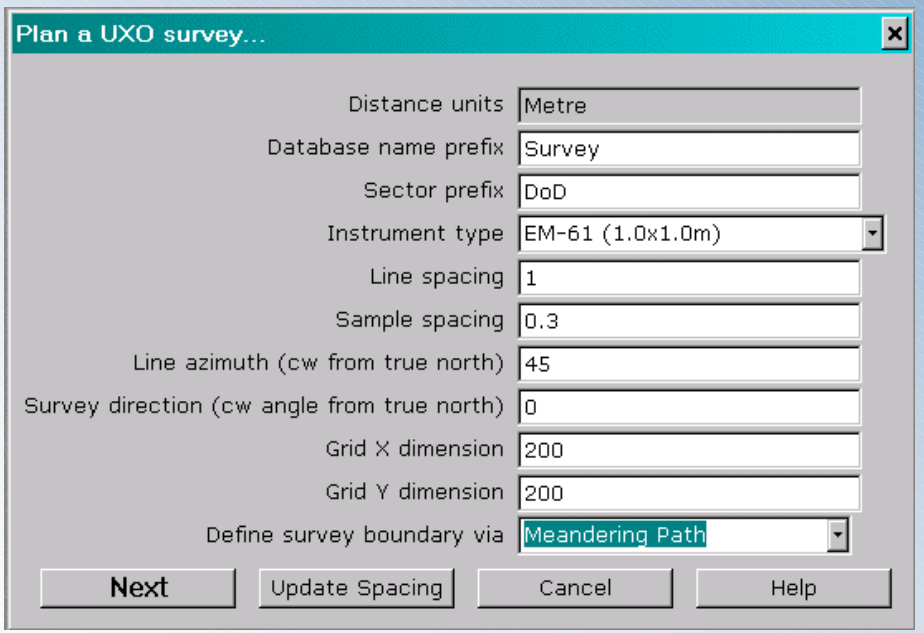
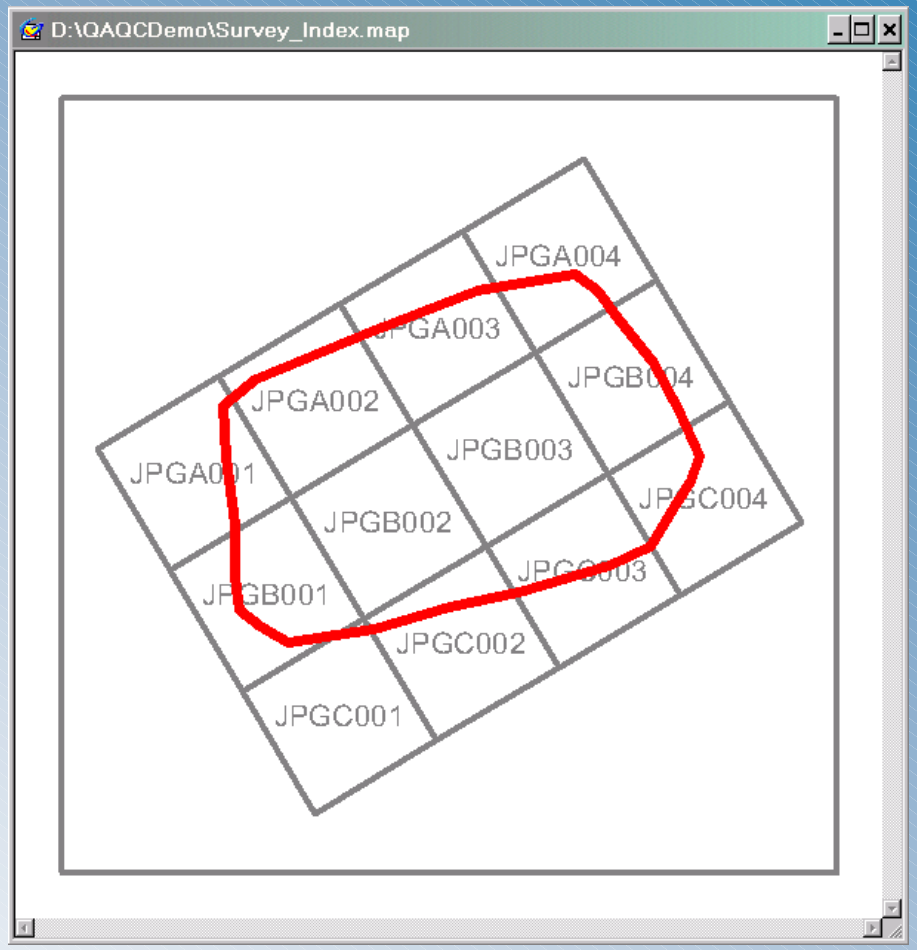
Plan a UXO Survey





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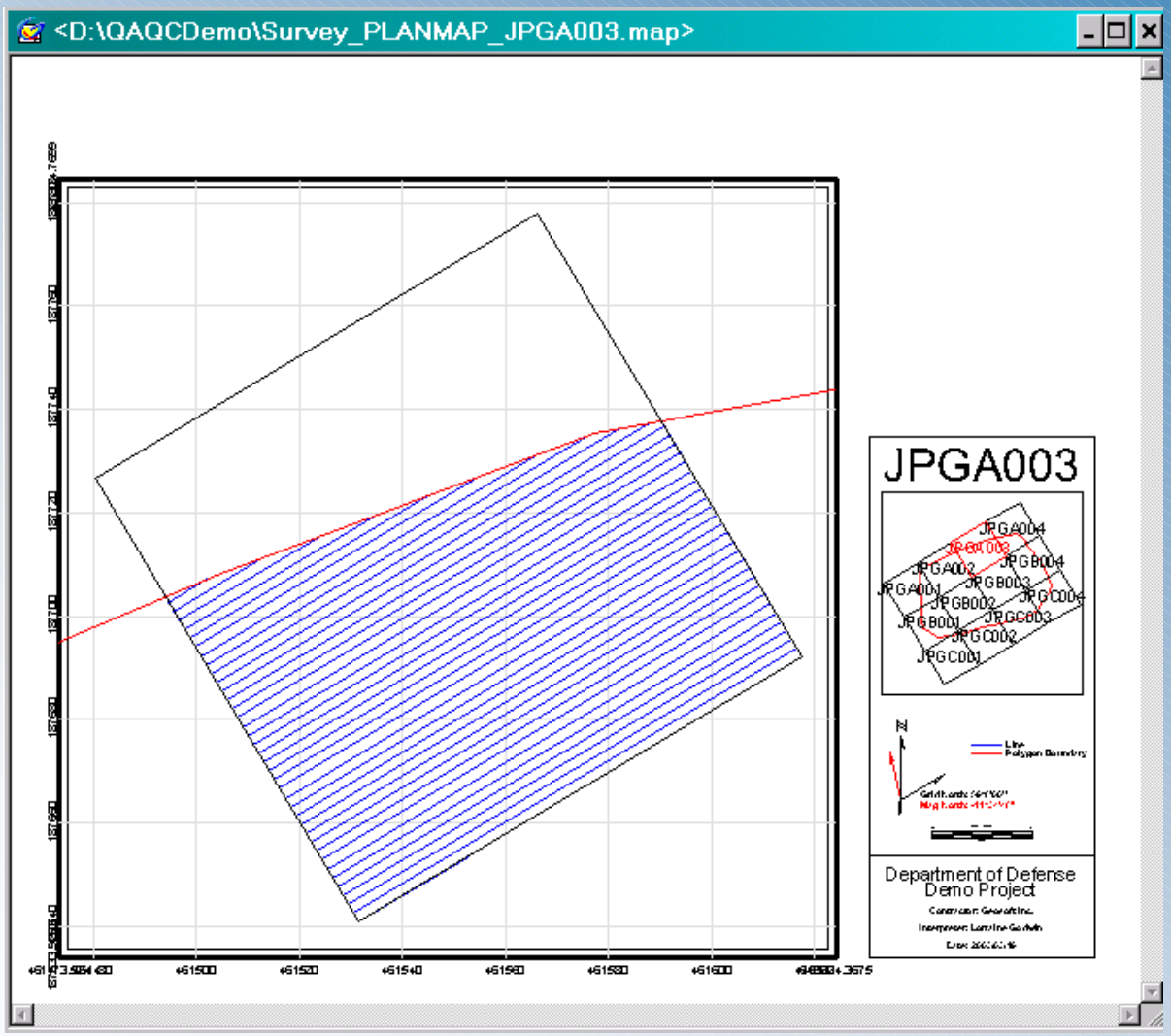
Survey Maps



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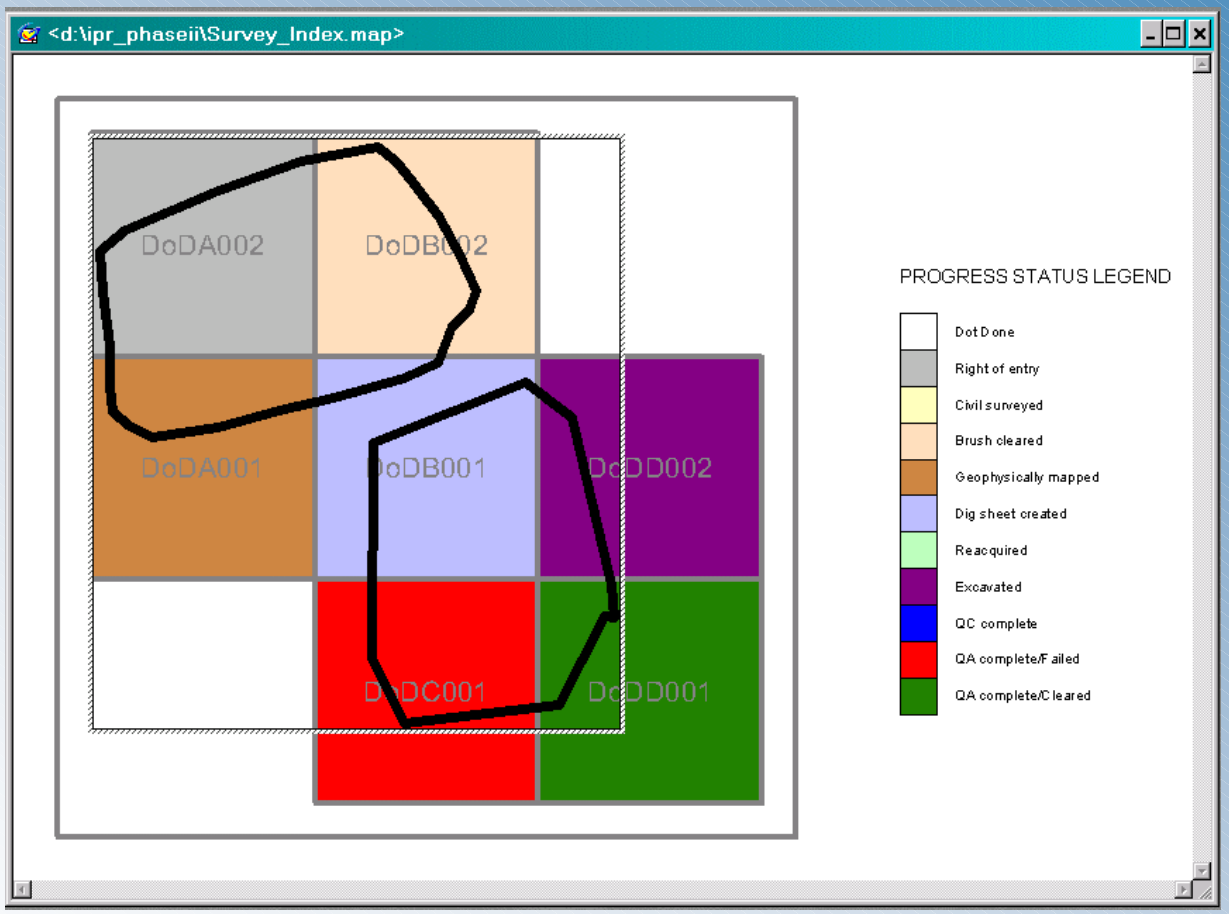
Progress Status Report



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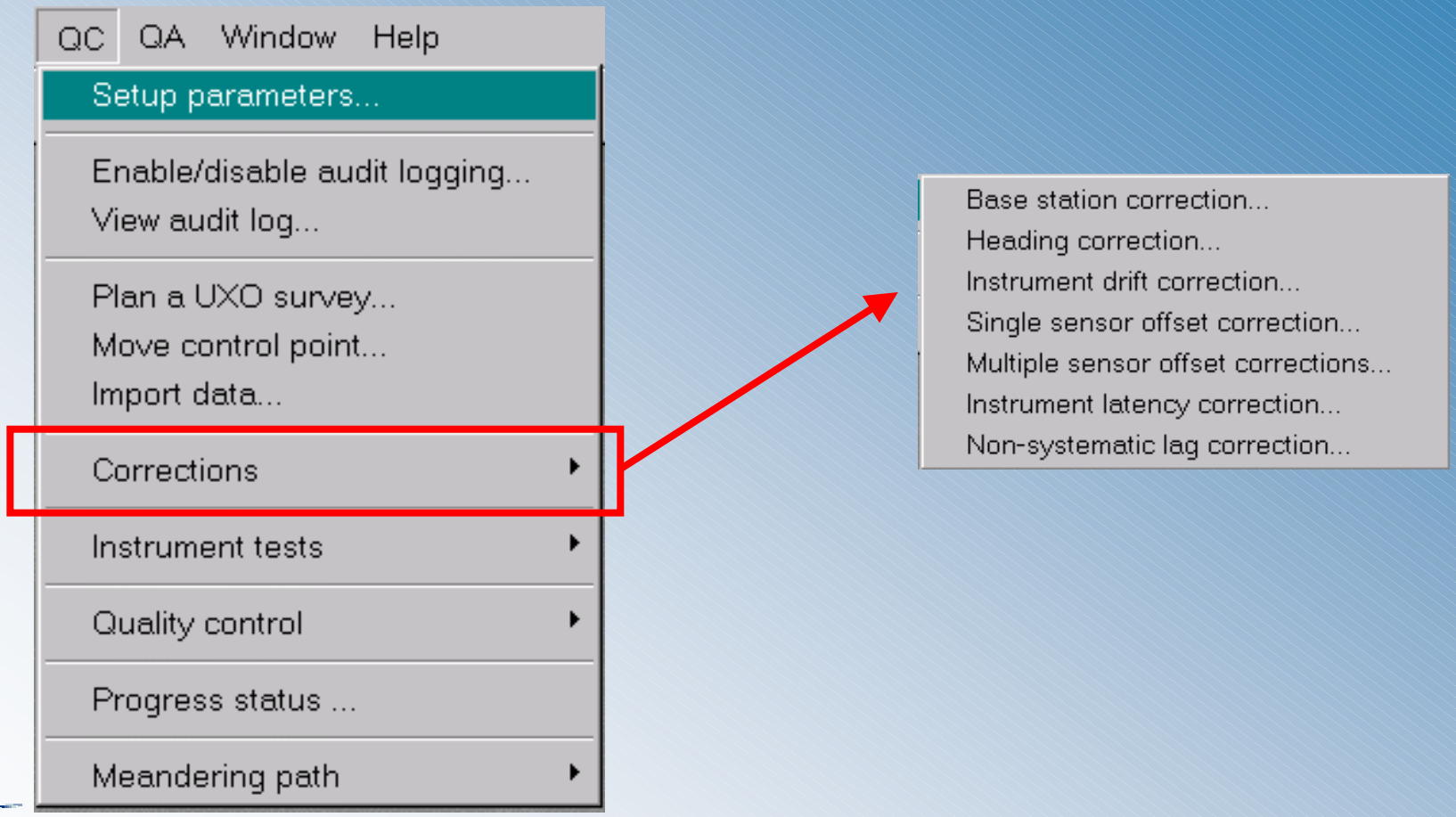
Data Corrections



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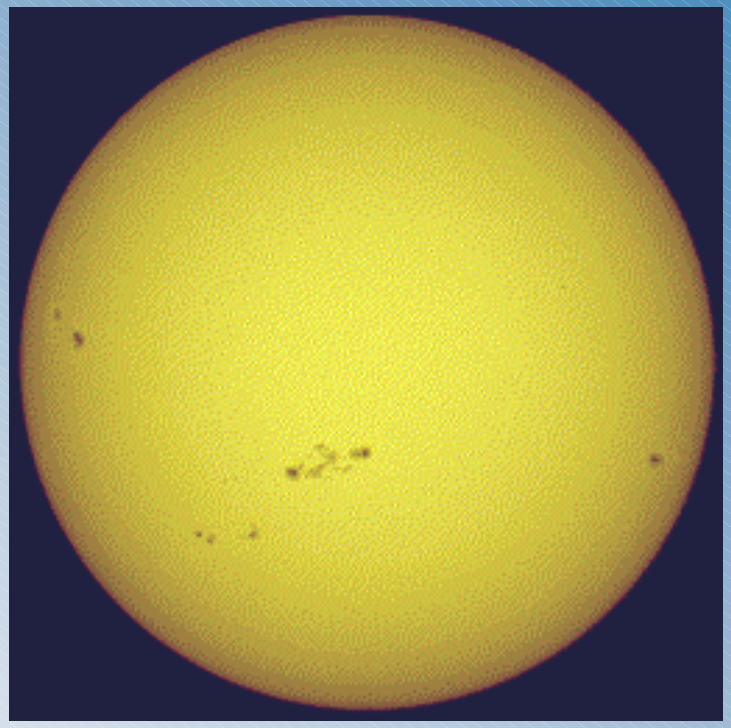
Diurnal Variations

- earth’s magnetic field intensity varies naturally as the earth rotates in the ionosphere (solar wind) of the sun
- “diurnal” because the variation has a natural period of one day
- magnetic storms (from sun spots) can shake the field by 100's of nT over a few minutes



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Magnetic Storms

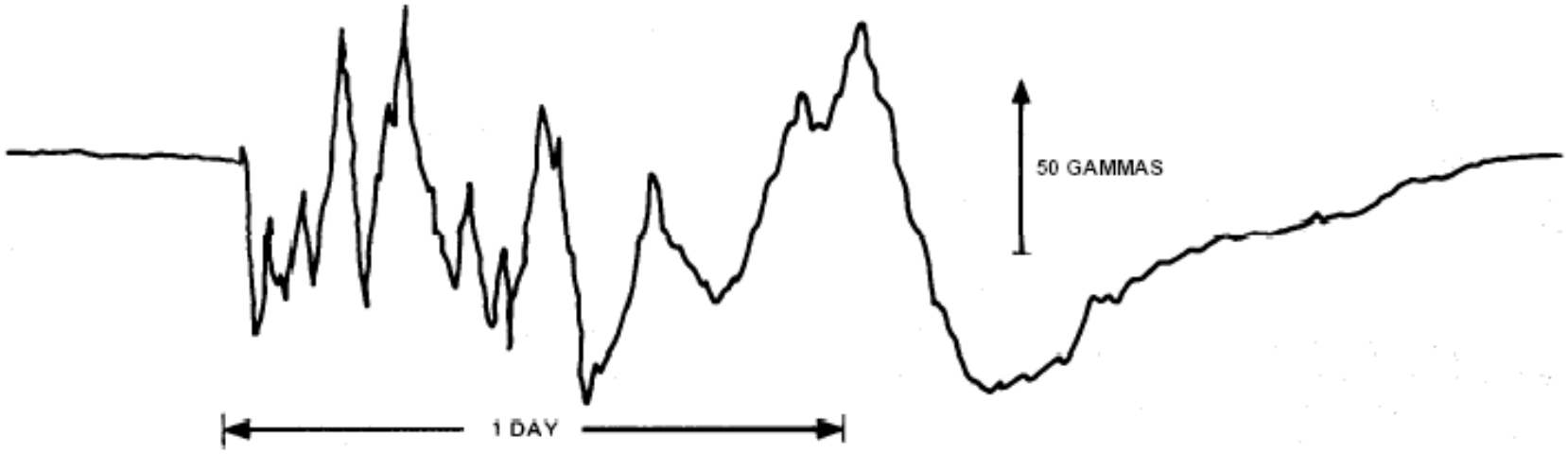

Figure 7. Typical Magnetic Storm

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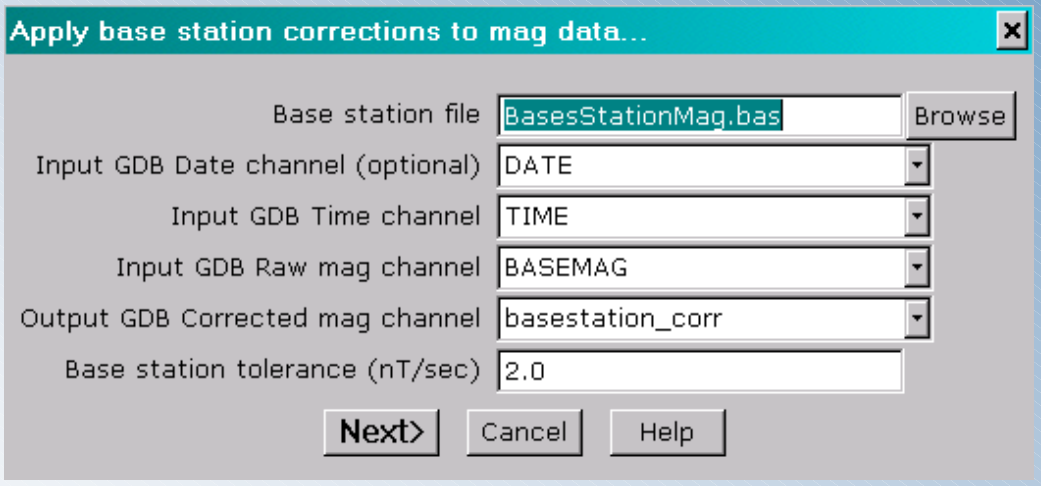
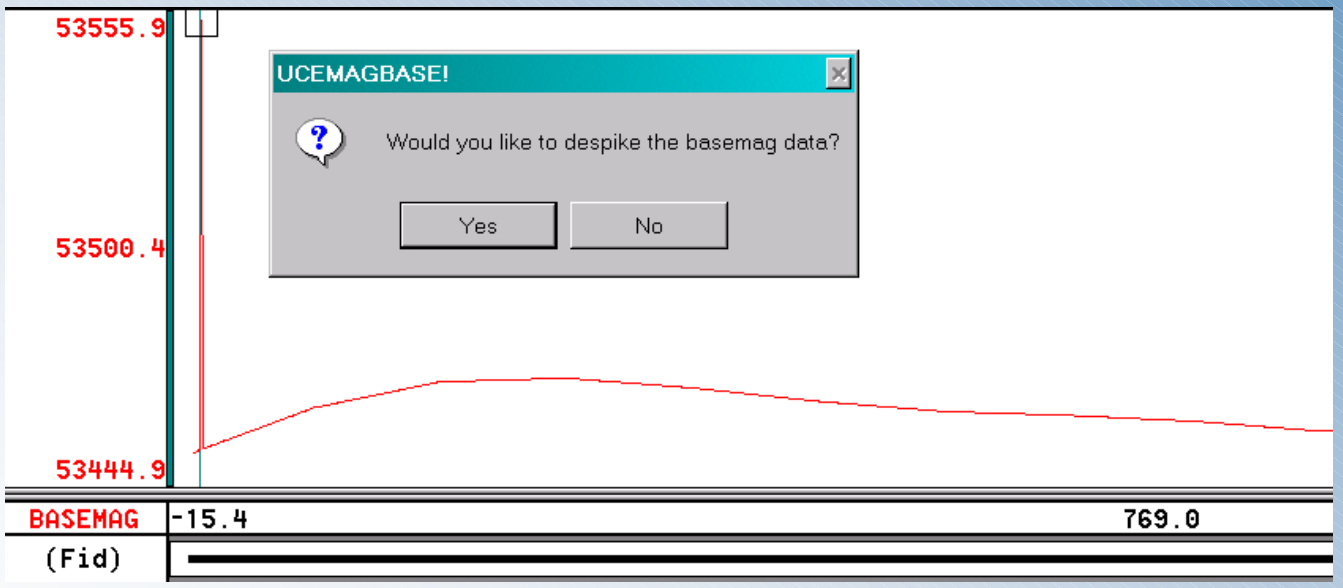
Base Station Correction





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Lag Problems

- instrument is being towed behind or in front of the data logger
- readings need to be shifted back over top of where they should be
- also introduced into data when the instrument is in automatic data collection mode and operator varies their walking speed and/or is surveying in mountainous terrain

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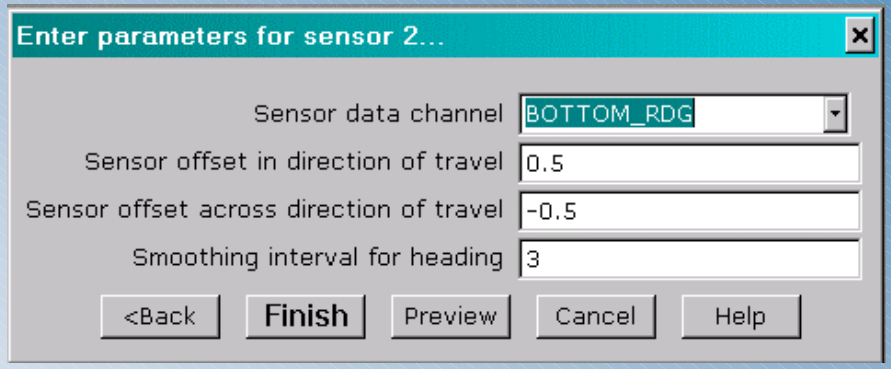
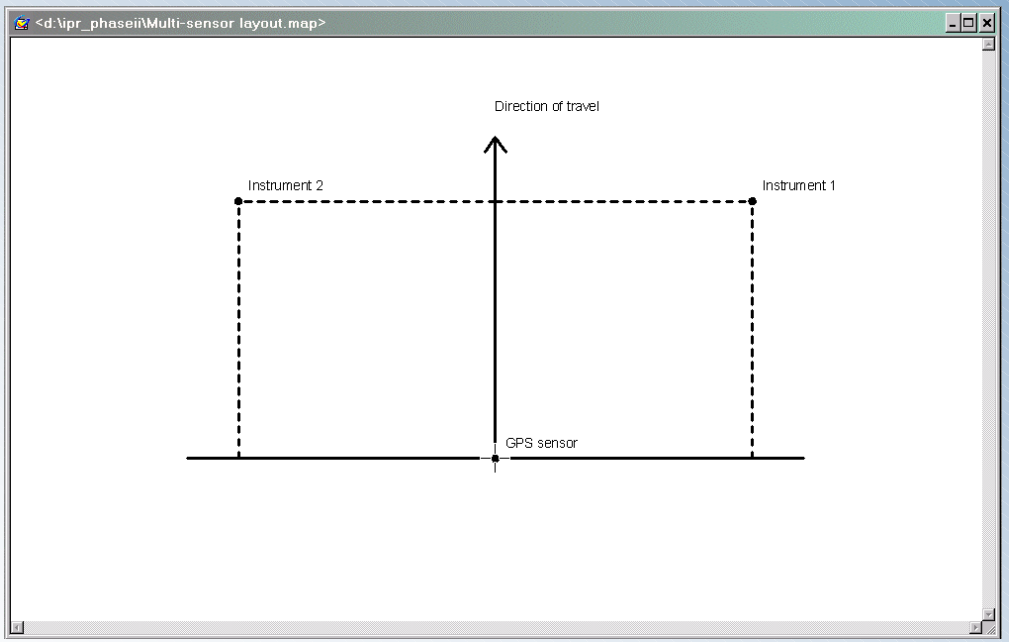
Lag Correction





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Heading Problems

- mag sensor position doesn't always point in the same direction during a survey
- heading errors due to variable positions of sensor, operator, and mag console relative to one another in the primary magnetic field
- systematic shift in data
- heading problems can introduce errors of 1-2 nT in data

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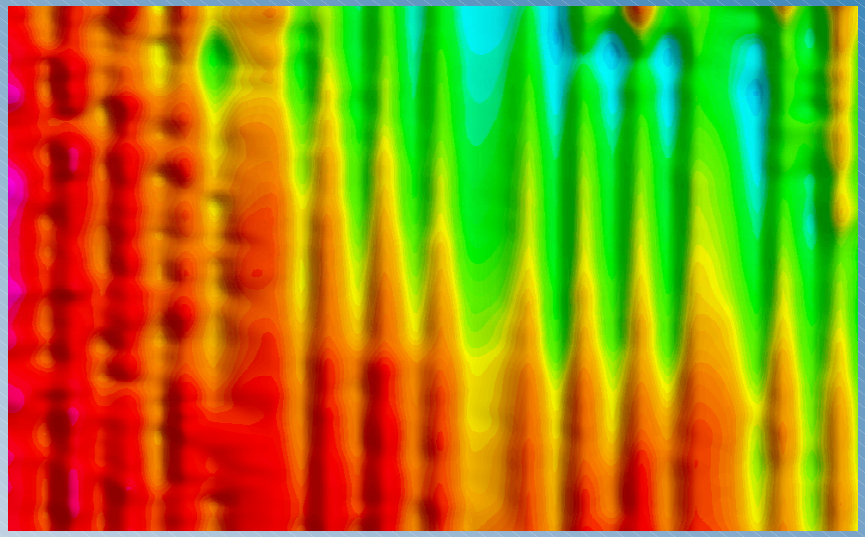
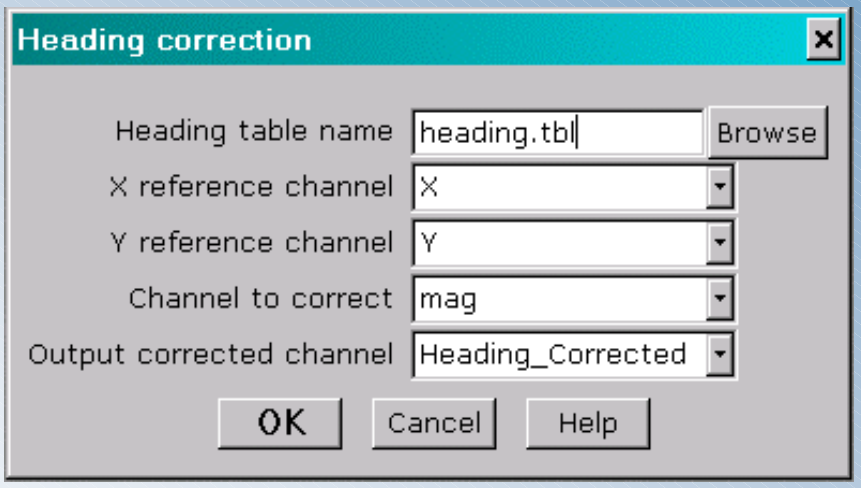
Heading Correction

- heading problems show up as “striping” on a map
- take readings in different directions (N, S, E and W) with mag while collecting continuous readings
- create a heading table





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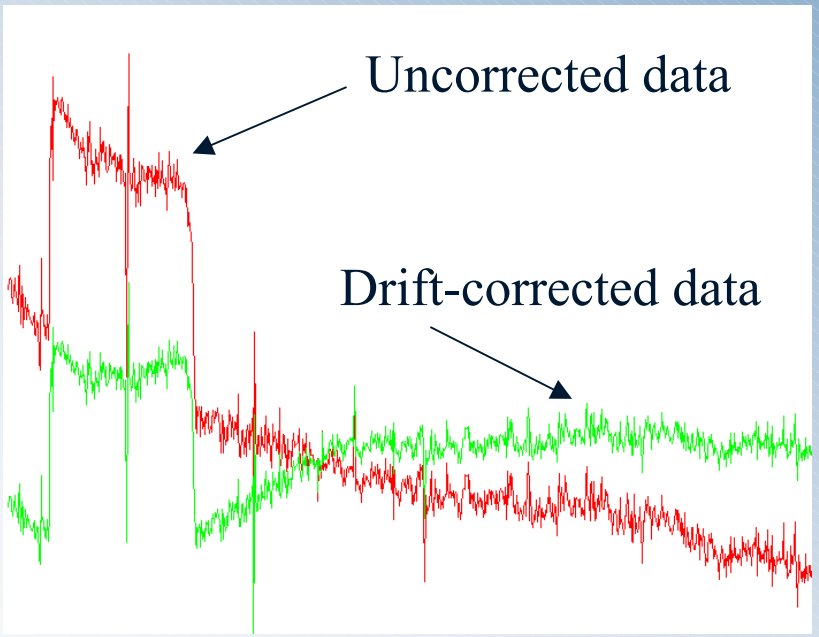
Instrument Drift



- thermal changes in the instrument throughout the day
- causes sensor drift
- due to instrument electronics heating up
- EM-61 can drift several mV over course of a day

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Solution: Drift Correction

- Allow instrument to warm up prior to use; or
- Use test line at beginning of day and end of day; or
- Manually correct lines by examining profiles; or

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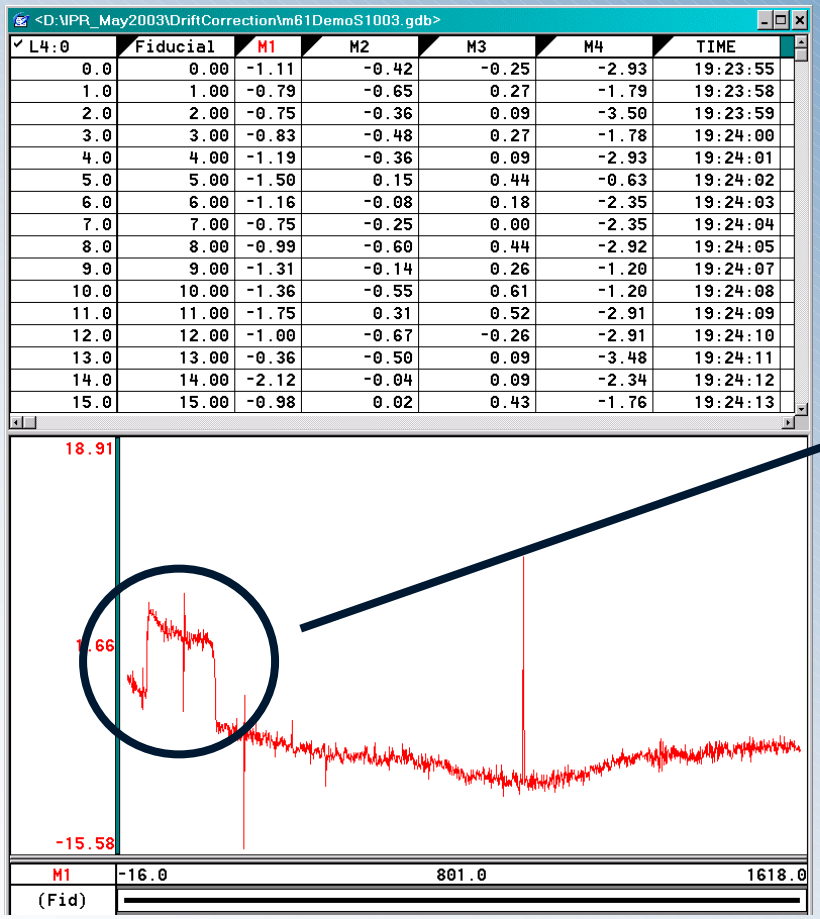
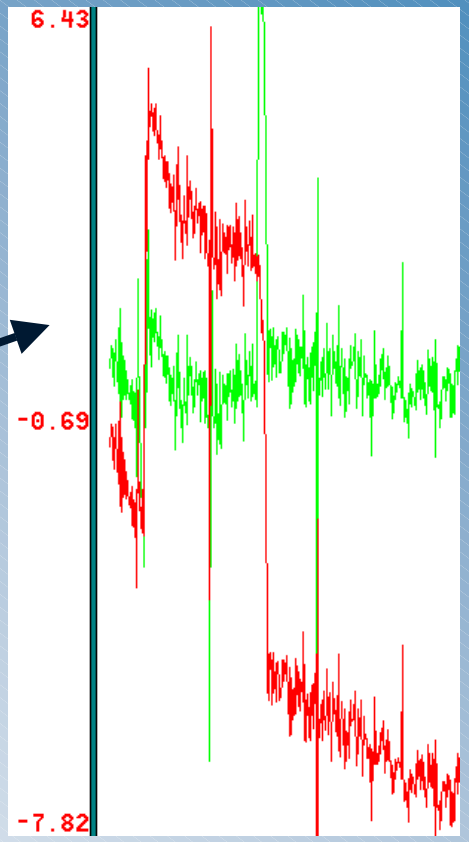
Drift Corrections





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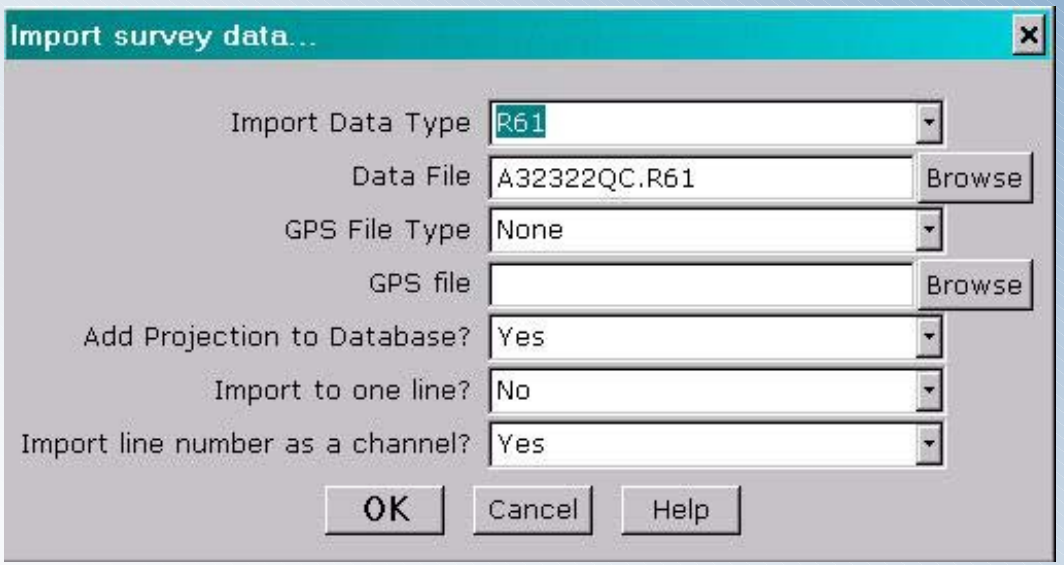
EM Data Corrections

EM Data Corrections

- Import raw Geonics dump files (*.R61)
- Correct line names, directions, start/end stations
- Adjust fiducial locations
- Merge survey data with GPS data



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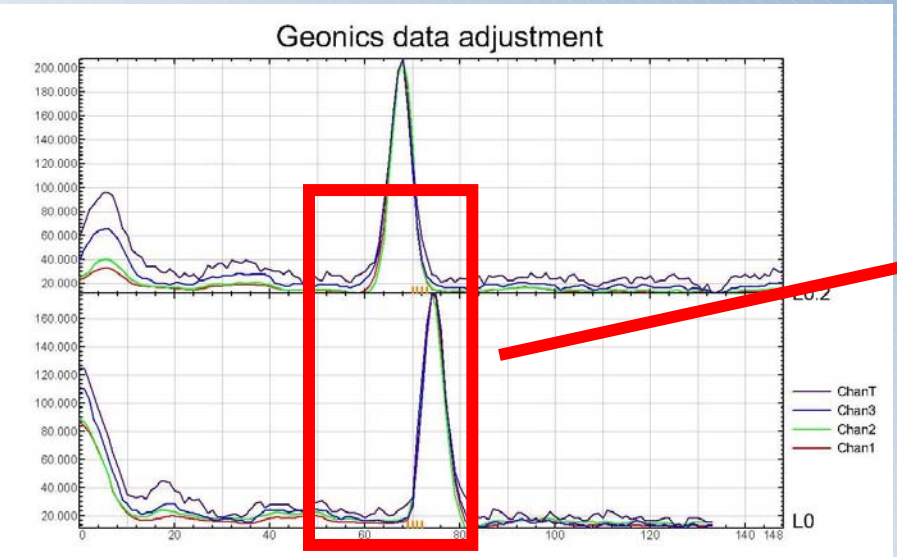
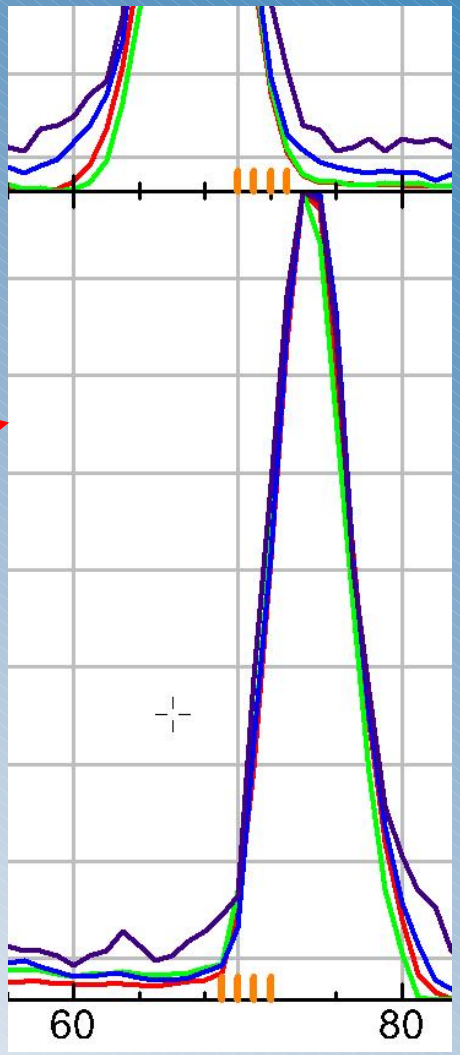
EM Data Corrections





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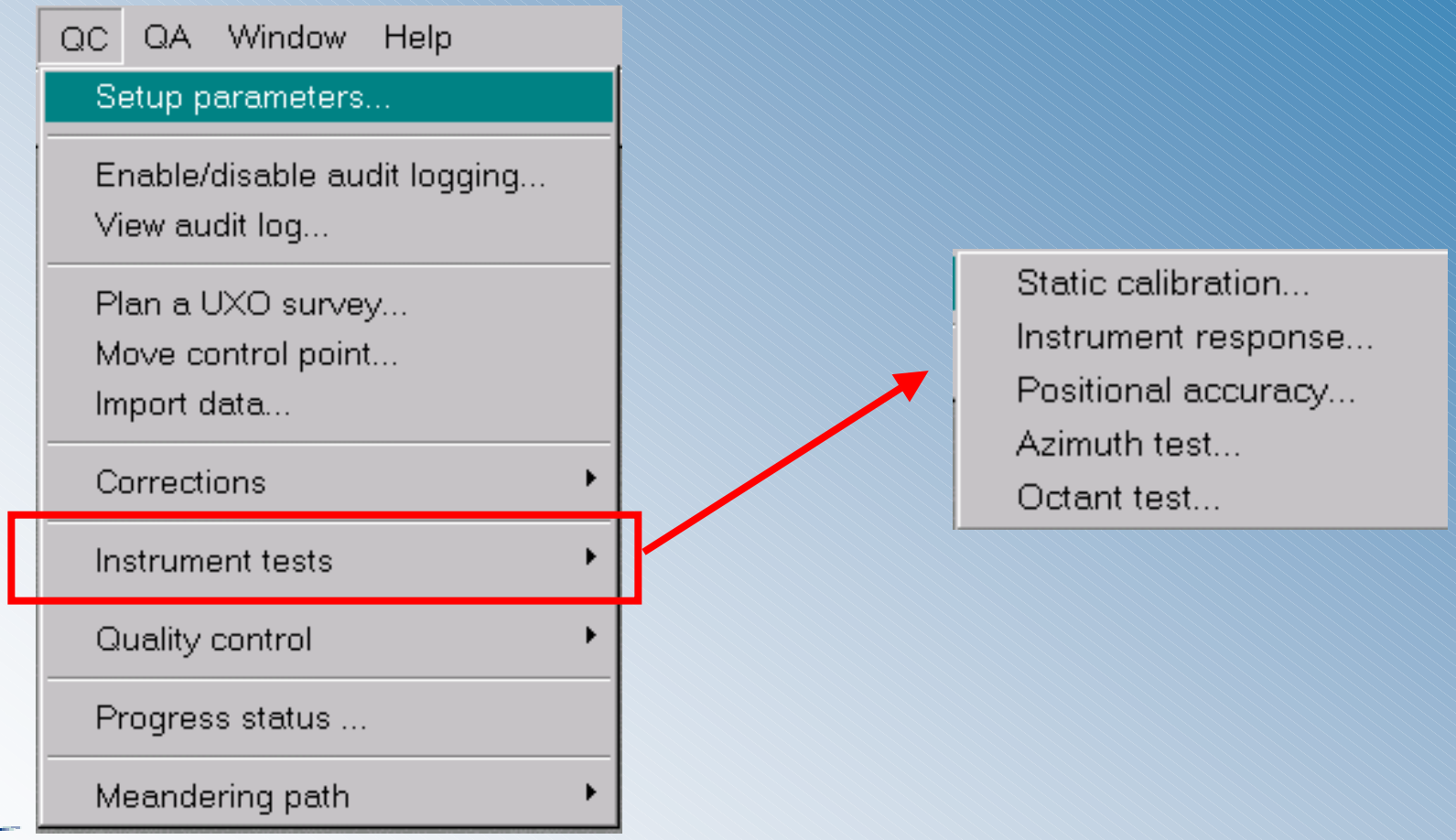
Instrument Tests



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Instrument Height Test

- Task: Instrument Tests
- Add statistics to height optimization test map

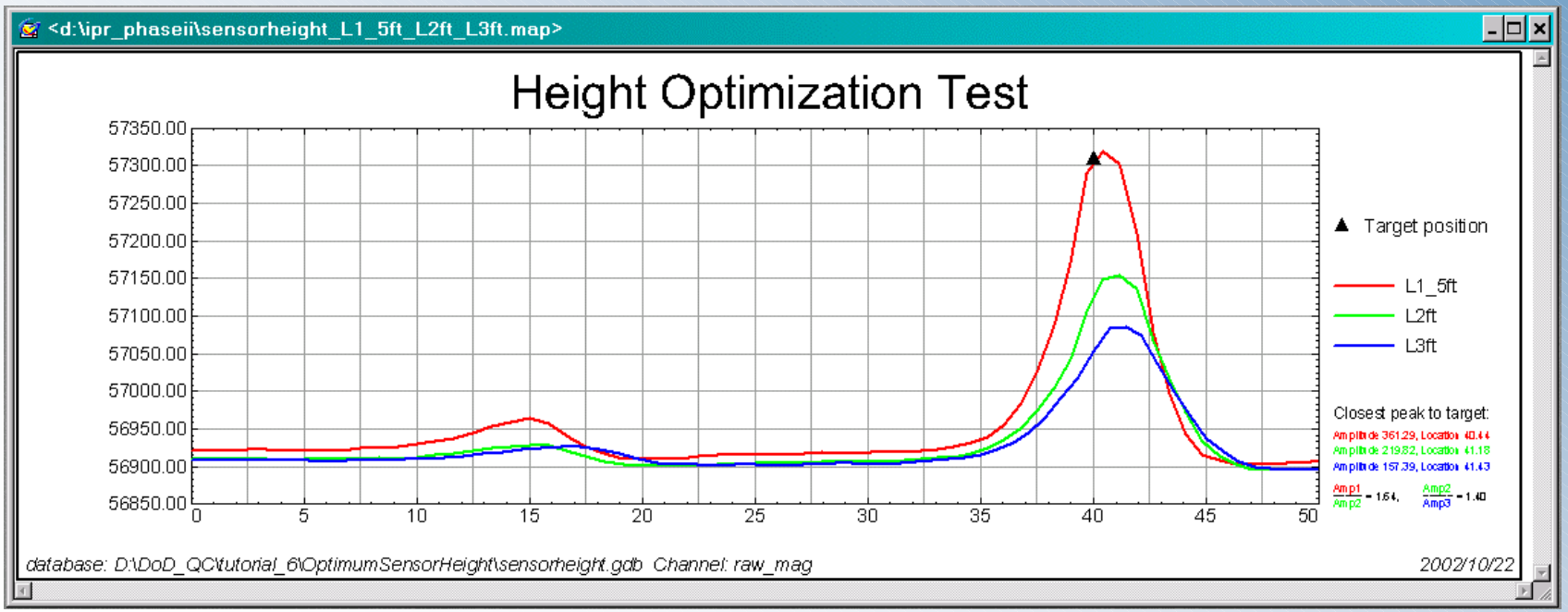
Closest peak to target:

Amplitude 361.29, Location 40.44

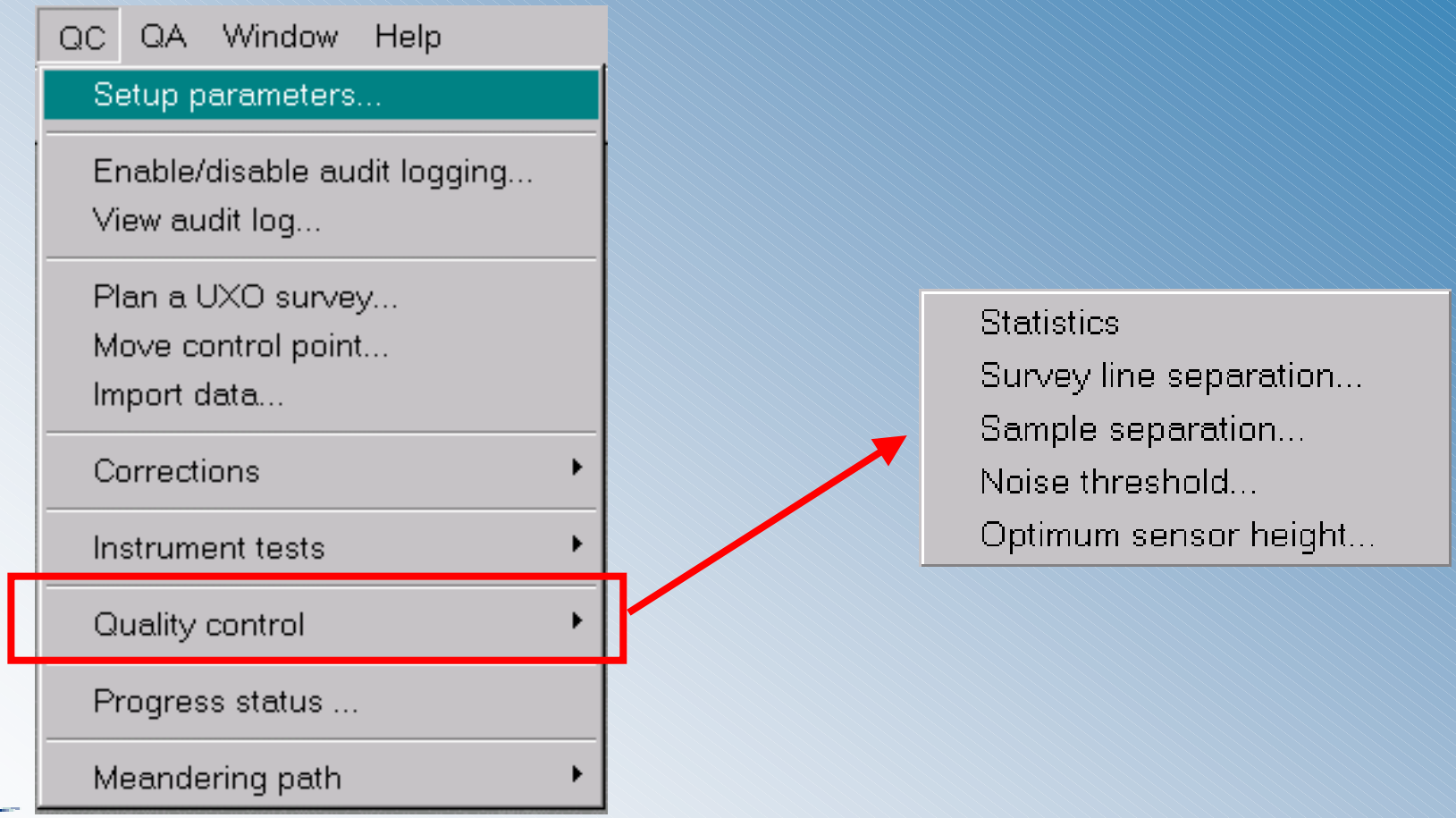
Amplitude 219.82, Location 41.18

Amplitude 157.39, Location 41.43

$\frac{\text{Amp1}}{\text{Amp2}} = 1.64,$ $\frac{\text{Amp2}}{\text{Amp3}} = 1.40$



Quality Control Tests



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Survey Statistics

stats.txt - Notepad

File Edit Format Help

Channel: Line Number	Total_Field Minimum	Maximum	Mean	Median	Mode	Std.dev.	1st diff.StD.	4th dif
L0:0	53082.01	54017.88	53462.50	53471.96	53462.21	61.05	49.94	174.98
L1:0	53387.45	53517.07	53457.56	53457.66	53453.61	14.47	9.09	36.04
L2:0	53422.46	53563.07	53458.68	53457.61	53456.15	13.31	7.20	23.35
L3:0	53412.36	53507.18	53456.22	53455.82	53454.83	10.18	6.26	27.03
L4:0	53435.09	53505.61	53456.56	53457.13	53454.92	6.98	4.29	15.88
L5:0	53431.15	53471.21	53452.02	53452.85	53453.27	5.33	3.73	16.84
L6:0	53430.65	53515.27	53457.75	53458.86	53457.98	9.43	6.50	25.44
L7:0	53021.52	53487.64	53450.20	53458.51	53453.65	32.11	23.93	74.97
L8:0	53389.81	53516.62	53454.83	53455.86	53454.54	11.39	6.41	21.78
L9:0	53353.63	53481.15	53448.92	53451.93	53453.25	12.14	7.76	28.53
L10:0	53410.58	54041.61	53456.40	53463.17	53456.59	35.80	37.73	178.77
L11:0	53302.07	53573.62	53450.24	53454.82	53451.99	17.27	13.64	50.72
L12:0	53419.46	53510.30	53453.30	53455.42	53456.36	10.14	6.18	24.17
L13:0	53400.65	53479.51	53450.87	53453.22	53452.40	8.97	4.94	21.80
L14:0	53418.01	53510.86	53455.15	53456.70	53459.60	8.69	4.95	18.96
L15:0	53374.96	53621.08	53453.83	53451.87	53449.31	18.63	13.10	45.15
L16:0	53421.00	53566.96	53455.79	53457.49	53455.97	13.87	7.49	22.60
L17:0	53370.05	53643.73	53449.14	53455.58	53452.72	18.94	16.66	95.01
L18:0	53331.04	53491.87	53450.94	53455.01	53449.99	15.27	9.70	37.63
L19:0	53308.04	53482.82	53446.71	53453.69	53451.87	22.50	5.40	17.61
L20:0	53286.17	53574.91	53452.46	53460.62	53463.62	33.95	10.46	31.88
L21:0	51892.01	53505.67	53425.29	53472.05	53455.24	182.29	39.76	35.83
L22:0	52047.26	53642.49	53426.96	53476.32	53459.70	199.21	37.67	66.73
L23:0	53343.24	53540.82	53455.65	53458.49	53456.44	15.87	9.49	34.17
L24:0	53374.18	53548.31	53458.36	53461.24	53455.80	13.94	8.91	34.56
L25:0	53337.87	53974.24	53460.26	53457.19	53450.56	43.09	43.64	87.96
L26:0	53416.38	53825.35	53463.27	53458.98	53454.72	33.70	23.07	101.71
L27:0	53439.92	53608.05	53497.72	53478.45	53467.94	50.39	23.93	35.70
L28:0	53446.32	53687.27	53504.63	53471.42	53466.40	72.07	36.24	66.98
L29:0	53462.18	53541.11	53488.04	53481.91	53463.00	26.41	13.09	19.71
L30:0	53464.36	53483.16	53469.22	53466.32	53465.34	6.36	2.49	8.44
L31:0	53296.50	53582.29	53455.51	53457.26	53454.28	20.19	17.82	84.91

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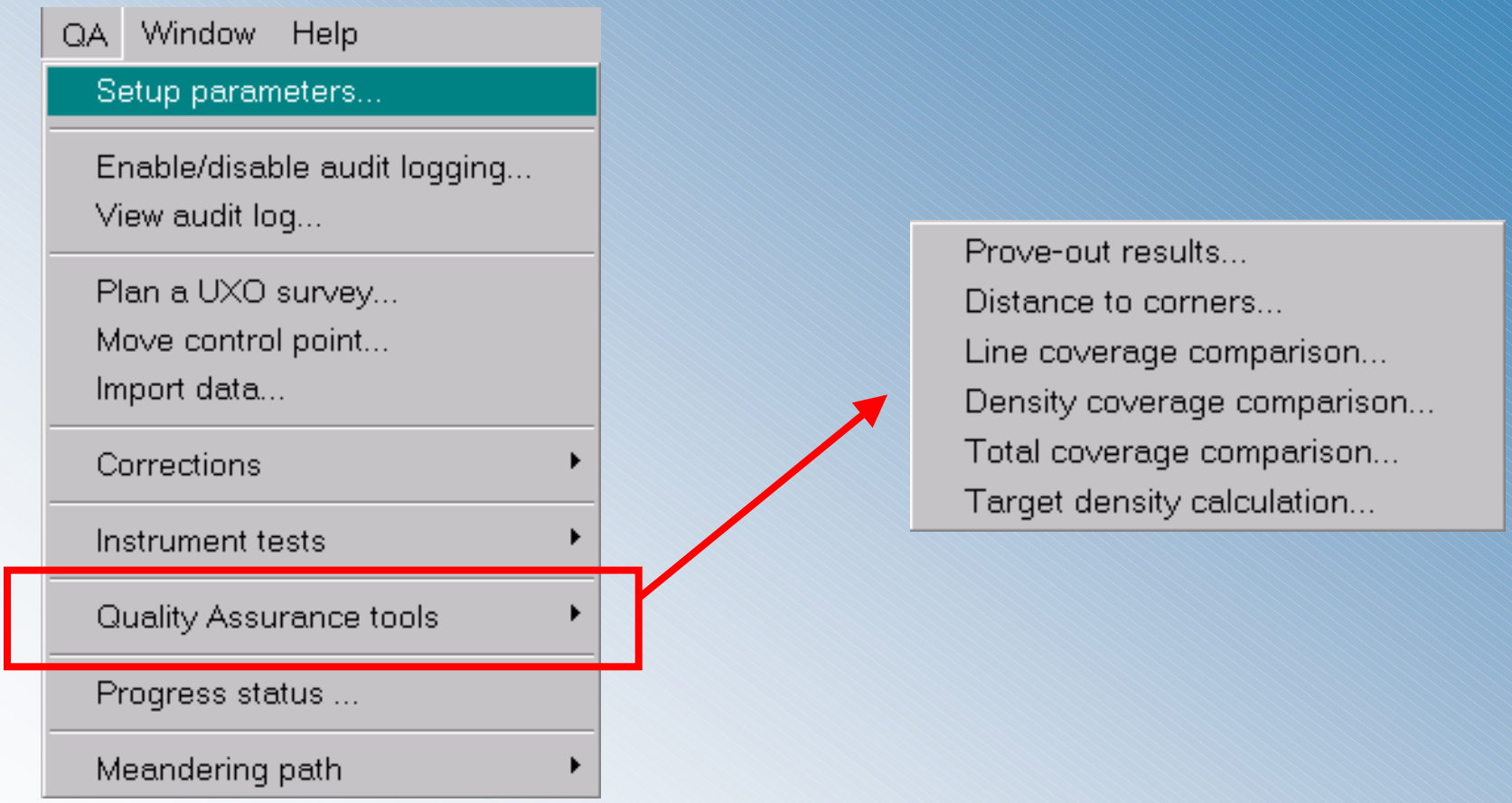
Quality Assurance Tools



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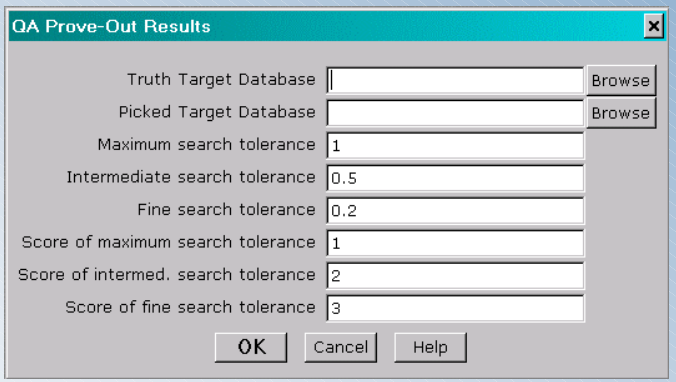
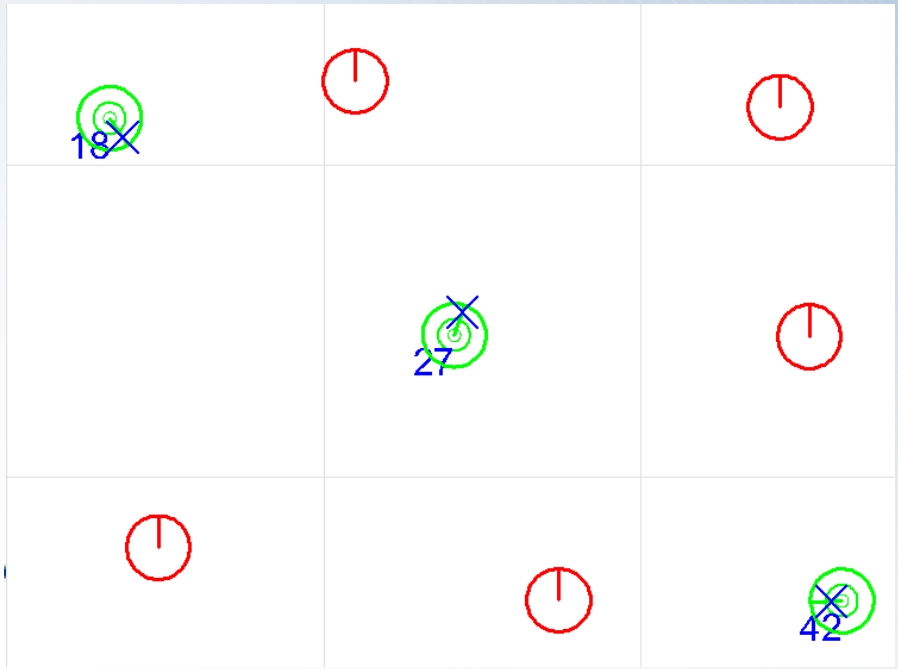
Prove Out Results



Task: Prove Out Map

- Add "bulls-eye" pictorial representation to maps
- Add target statistics to map



Targets found within radius of 1 m : 15
Targets found within radius of 0.5 m : 7
Total Number of targets reported: 22
Total Number of truth targets: 41
Total Score: 29

Success To Date

- QA/QC tools are being used on a variety of UXO sites
- CEHNC will compare data collected prior to tools being released to verify if data quality has improved
- Analysis algorithms are already being developed by multiple groups (e.g. AETC, ERDC, Zonge)

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Contractors Using Software

- AETC
- American Tech. Inc.
- Apex Environmental
- Blackhawk
- Booz, Allen, Hamilton
- Dillon Consulting (Canada)
- Donaldson Enterprises
- Earth Tech
- ECC
- Environmental Mapping
- Foster Wheeler
- Geophex
- NAEVA Geophysics
- G-tek (Australia)
- Parsons
- SAIC
- Tetra Tech
- UXB
- Weston Solutions
- Zapata Engineering
- Zonge

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Future Development

- MTADS support (with AETC)
- Geophex algorithms
- ECC algorithms
- PNL VSP algorithms
- EM modeling research
- Enhancements/additions
- Preparation for real-time mapping
- Broaden scope for other facets of DoD

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Training on QA/QC Software

- Huntsville Center will be hosting a training session (potentially in Huntsville) in October 2003
- All facets of DoD are invited to participate
- Other training can be arranged with Geosoft at alternate locations

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Questions/Feedback?

- Software available upon request.
- Technical support available by Geosoft.
- POC: Geosoft Inc.
- All feedback is appreciated.

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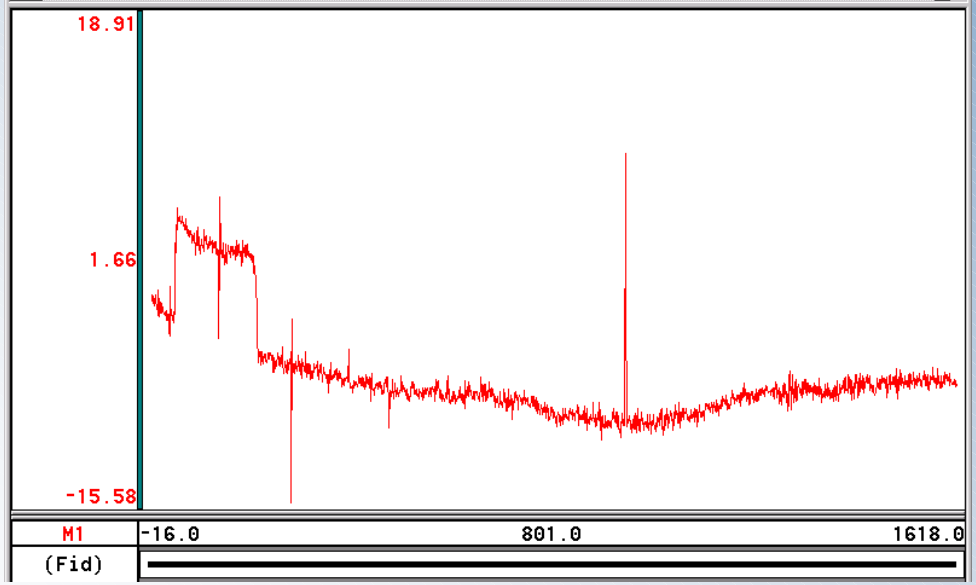
<D:\IPR_May2003\DriftCorrection\m61DemoS1003.gdb>

L4:0	Fiducial	M1	M2	M3	M4	TIME
0.0	0.00	-1.11	-0.42	-0.25	-2.93	19:23:55
1.0	1.00	-0.79	-0.65	0.27	-1.79	19:23:58
2.0	2.00	-0.75	-0.36	0.09	-3.50	19:23:59
3.0	3.00	-0.83	-0.48	0.27	-1.78	19:24:00
4.0	4.00	-1.19	-0.36	0.09	-2.93	19:24:01
5.0	5.00	-1.50	0.15	0.44	-0.63	19:24:02
6.0	6.00	-1.16	-0.08	0.18	-2.35	19:24:03
7.0	7.00	-0.75	-0.25	0.00	-2.35	19:24:04
8.0	8.00	-0.99	-0.60	0.44	-2.92	19:24:05
9.0	9.00	-1.31	-0.14	0.26	-1.20	19:24:07
10.0	10.00	-1.36	-0.55	0.61	-1.20	19:24:08
11.0	11.00	-1.75	0.31	0.52	-2.91	19:24:09
12.0	12.00	-1.00	-0.67	-0.26	-2.91	19:24:10
13.0	13.00	-0.36	-0.50	0.09	-3.48	19:24:11
14.0	14.00	-2.12	-0.04	0.09	-2.34	19:24:12
15.0	15.00	-0.98	0.02	0.43	-1.76	19:24:13



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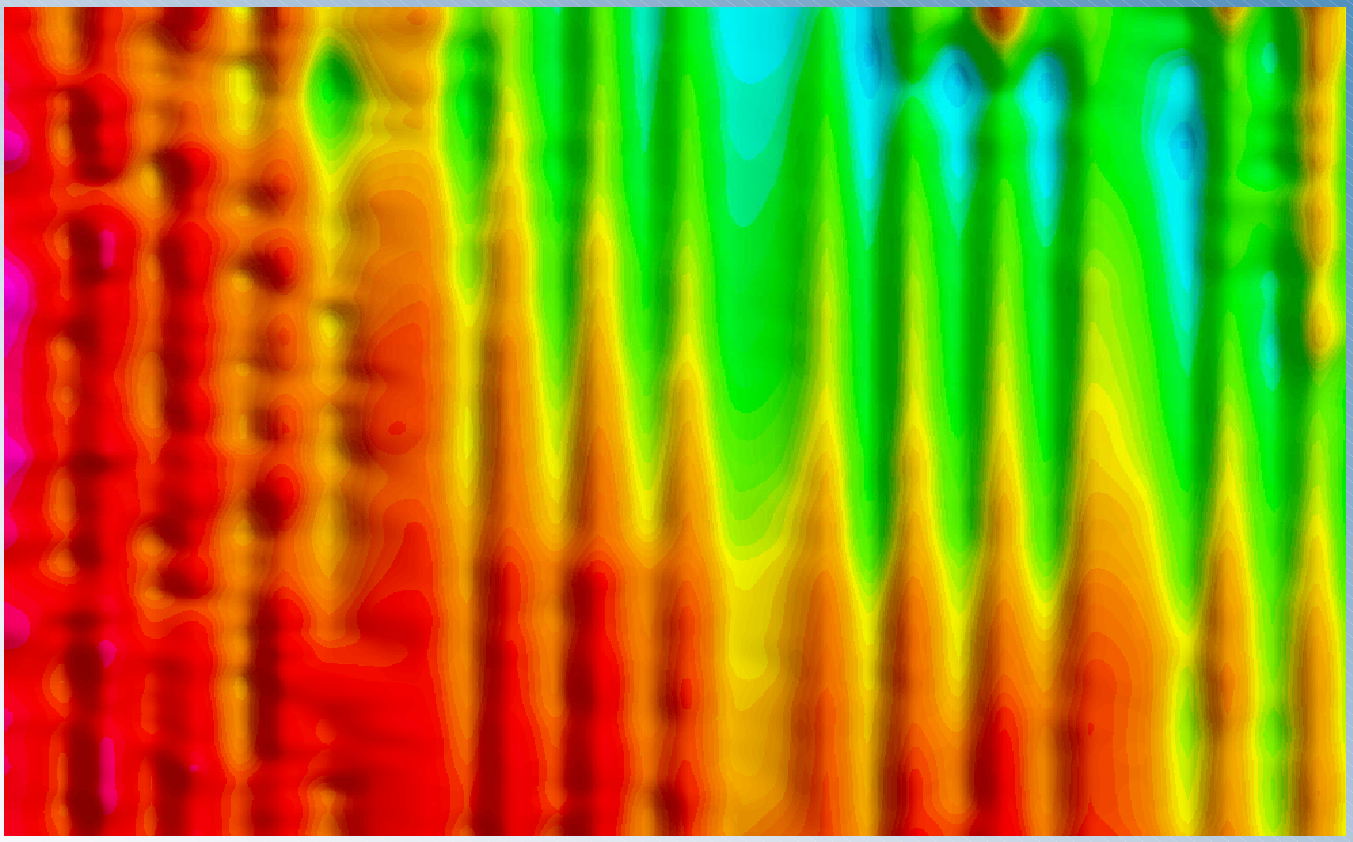

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